DOCUMENTATION OF DECISION-AIDING SOFTWARE:

DECISION FUNCTIONAL DESCRIPTION

DECISIONS AND DESIGNS INC.

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November 1979

N0001 4-79-C-0069

ADVANCED DECISION TECHNOLOGY PROGRAM

CYBERNETICS TECHNOLOGY OFFICE
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Office of Naval Research • Engineering Psychology Programs

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by

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Sponsored by

Defense Advanced Research Projects Agency
ARPA Order 3469

November 1979

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DECISION FUNCTIONAL DESCRIPTION

1.0 INTRODUCTION

1.1 Purpose of the Functional Description

This Functional Description provides a technical delineation of the specific functions that DECISION must perform. It serves as a formal basis for mutual understanding between the functional designer of the system and the software development personnel. Together with the DECISION System Specification, it serves as the basic documentation for system development and implementation.

1.2 References

1.2.1 Barclay, Scott, et al. Handbook for Decision Analysis. Technical Report 77-6-30. McLean, Virginia: Decisions and Designs, Inc., September 1977.

1.2.2 Allardyce, Linda; Amey, Dorothy M.; Feuerwerger, Phillip H.; Gulick, Roy M. Documentation of Decision-Aiding Software: DECISION Users Manual. McLean, Virginia: Decisions and Designs, Inc., November 1979.

1.2.3 Allardyce, Linda; Amey, Dorothy M.; Feuerwerger, Phillip H.; Gulick, Roy M. Documentation of Decision-Aiding Software: DECISION System Specification. McLean, Virginia: Decisions and Designs, Inc., November 1979.

1.3 Terms and Abbreviations

1.3.1 DECISION - DECISION, the name of the system, is an abbreviation for Decision Tree, reflecting the system's major area of applicability.

1.3.2 Terms - Standard mathematical notations and decision-analytic terminology are used throughout this Functicnal Description. Decision-analytic terms are defined when they are first encountered. Reference 1.2.1 provides more detail on decision analysis, should it be desired.

2.0 SYSTEM SUMMARY

2.1 System Description

DECISION is a decision-analytic, model-building software system. Its general purpose is to aid decision makers by providing them a capability to construct, store, retrieve, exercise, and refine decision tree models of complex decision problems they face.

The decision tree model serves as an organizing framework for processing information about a decision problem. Decision analysis is the methodological tool with which the decision maker defines and exercises the Decision Tree model to evaluate the various decision alternatives pertaining to the problem.

The overall objective of DECISION is to ensure that the ultimate decision choice is a coherent one: a choice that is consistent with the decision maker's own value structure and belief about the likelihood of future events that will affect the decision outcome. For a complete description of the purpose and use of DECISION, see DECISION Users Manual, reference 1.2.2.

2.2 Design Objectives

The system is designed to be used interactively by end users who are relatively unsophisticated with respect to computer technology. Accordingly, the design satisfies two human-factors objectives: DECISION is a menu-driven system, and one that is generally forgiving of procedural errors by the user.

In addition, to facilitate the production of the program specification and coding necessary to implement DECISION at a physical site, the system is designed in a hierarchically structured and modular fashion. The logical structure of DECISION is contained in the manual, DECISION System Specification, reference 1.2.3.

3.0 DETAILED CHARACTERISTICS

The fundamental product of DECISION is a computer-based decision tree model. The DECISION system enables the user to create, store, retrieve, exercise, and refine decision tree models interactively. A typical decision tree is shown in Figure 3-1.

All of the specific functions that DECISION performs are related to a decision tree model. Therefore, in order to establish a frame of reference for understanding the various functions that DECISION performs, it is necessary to begin with a detailed description of the format, inputs, and outputs of a decision tree model. A description of the specific functions that DECISION performs appears in Section 4.0.

3.1 Model Description

Each decision tree model created by the user must have a unique label, and each is constructed by using the same generic format. The format always consists of all of the following elements which, when they are completely specified, uniquely define a decision tree model.

3.1.1 The primary decision - The decision of interest, appropriately labeled. The label is applied to the decision model as an entity and is used by the DECISION system to store and retrieve the model.

3.1.2 Primary decision alternatives - A list of the various alternative actions immediately available to the decision maker. Each alternative is appropriately labeled.

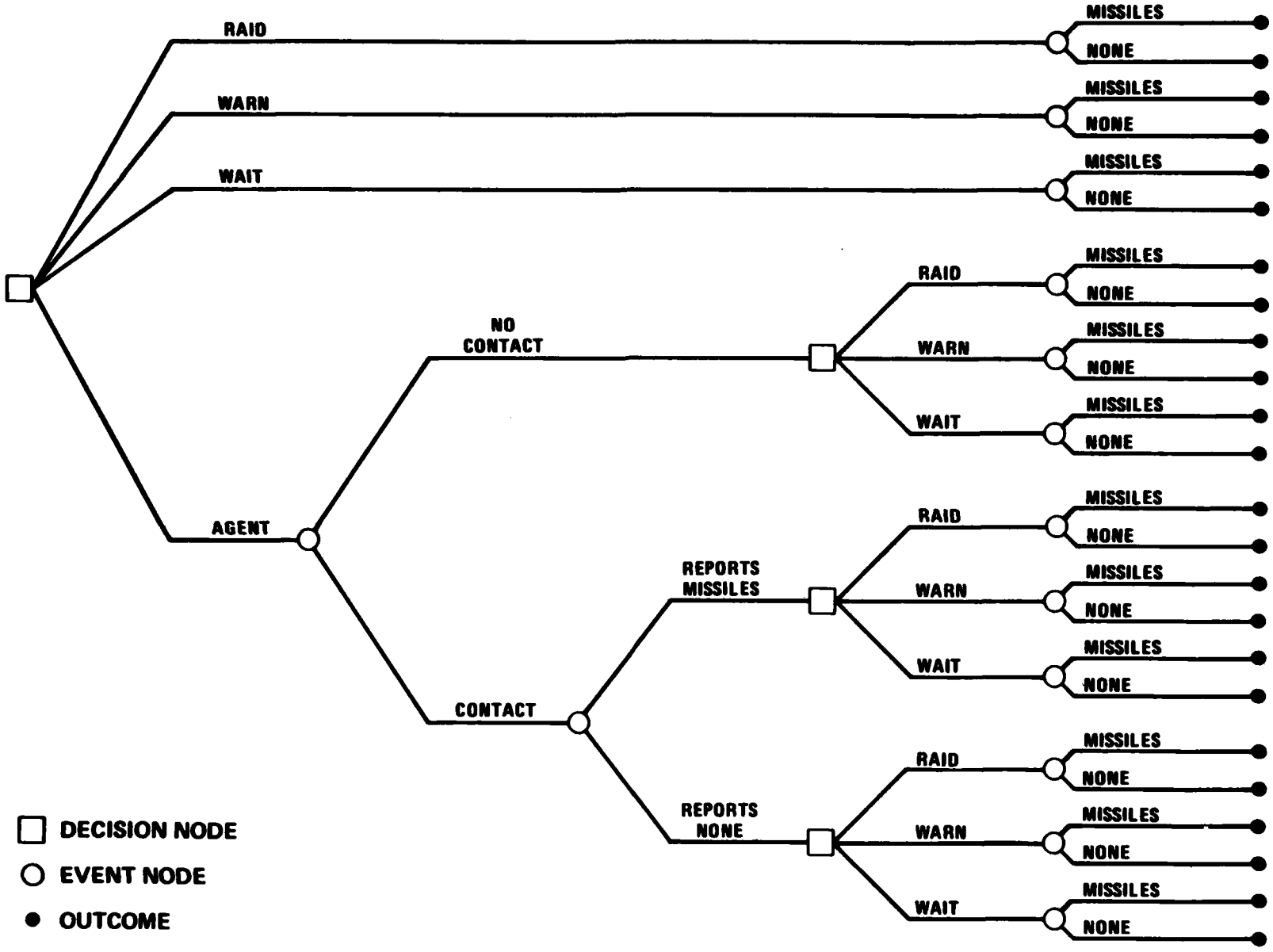

Figure 3-1

TYPICAL DECISION TREE

The primary decision alternatives in Figure 3-1 are: to raid, to warn, to wait, and to use an agent.

3.1.3 Information events - A list of the key events, appropriately labeled, whose future outcomes will influence the eventual success of the decision.

3.1.4 Event outcomes - For each future event, a list of the discrete outcomes, each appropriately labeled, that together define the universe of possibilities regarding the event's occurrence.

3.1.5 Subsequent decisions - A list of decisions, appropriately labeled, that will be faced by the decision maker in the future, after a particular occurrence of an event.

3.1.6 Subsequent decision alternatives - For each subsequent decision, a list of the various alternative actions available to the decision maker. Each alternative is appropriately labeled. For example, in Figure 3-1 if the primary decision is to use an agent but there is no contact, then the decision maker must decide to raid, to warn, or to wait.

3.1.7 Node specifications - A hierarchical numbering scheme that specifies the structural format of the decision tree. A typical scheme is shown in Figure 3-2. Note that each number refers to the node to its right. There are two types of nodes: decision nodes and event nodes. Decision nodes carry the designator D (decision node); event nodes carry the designator W (weighted node).

3.1.8 Decision outcomes - The elements discussed thus far define the structural framework of the decision tree

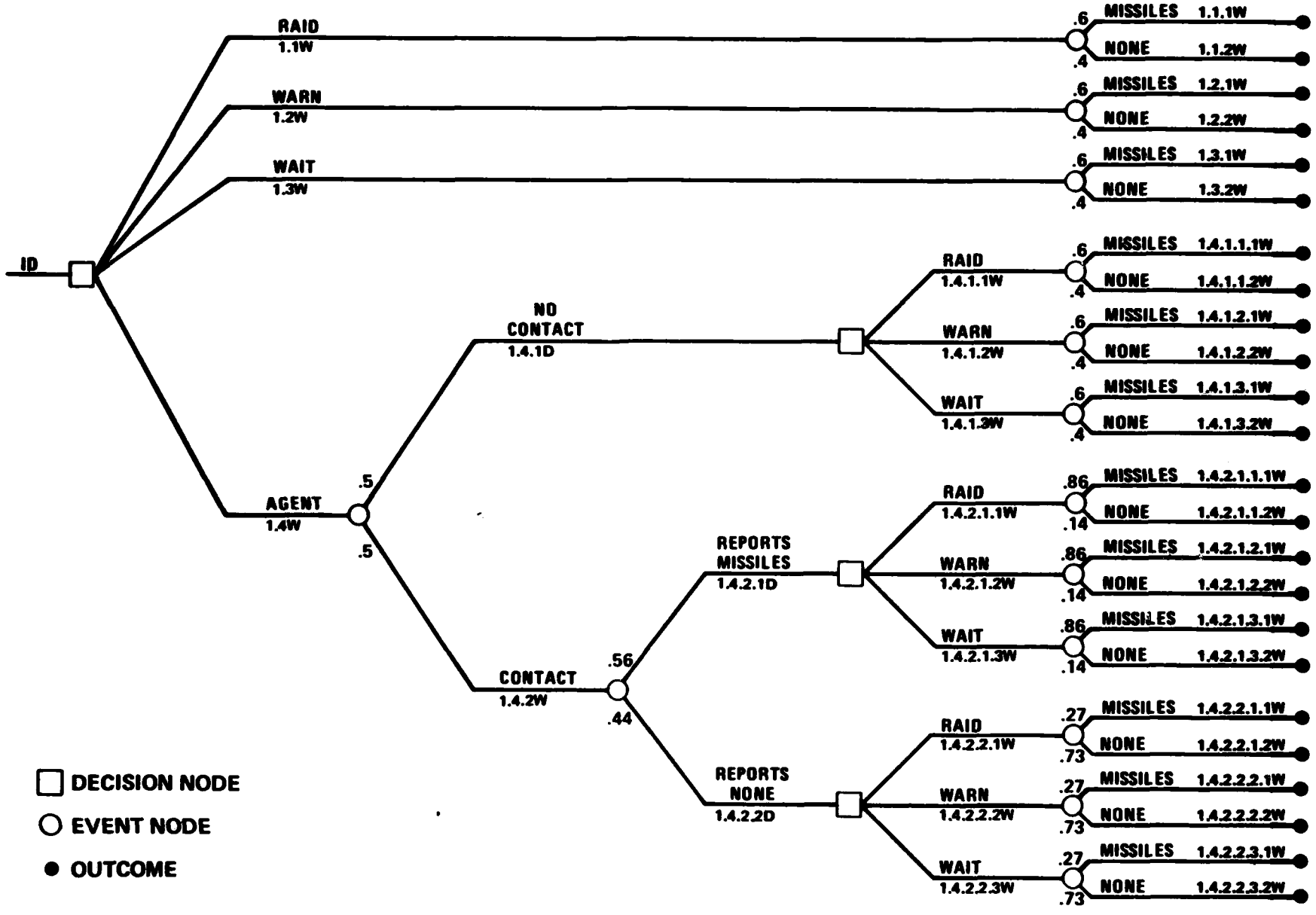

Figure 3-2

TYPICAL TREE - SPECIFIED

model. The collection of right-most nodes defines all of the possible outcomes of the decision problem.

The remaining elements of the model format are used to specify the preferences and beliefs of the decision maker.

3.1.9 Event probabilities - For each key event, a vector of probabilities that are associated with the possible outcomes. Each probability is a number between 0 and 1, inclusive, that represents the extent to which the decision maker believes that an event outcome will occur in the future. However, probabilities are often expressed as a percentage of certainty, e.g., as 40% vice 0.4.

3.1.10 Decision outcome criteria - A list of the various criteria, each appropriately labeled, by which the decision maker would judge the relative overall utility associated with the eventual decision outcome. For example, the relative satisfaction to the decision maker of the twenty-four outcomes shown on Figure 3-2 might be expressed in terms of three criteria: impact on domestic affairs, impact on foreign affairs, and impact on national security.

3.1.11 Criteria weights - A vector of importance weights associated with the decision outcome criteria. Each criterion weight is expressed numerically as a percentage of the whole, e.g., as 65%. The weights must sum to 100%.

3.1.12 Utilities - For each of the possible decision outcomes, the decision maker must specify its utility with respect to each of the criteria. A utility is a number between 0 and 1 that represents the relative degree of satisfaction to the decision maker. Utilities are normally

expressed as percentages of complete satisfaction, e.g., as 25%.

This completes the model format. The decision tree model is completely and uniquely specified when the elements described above have been completely defined by the user.

Figure 3-2 shows a typical tree with all of the specifications shown above except the criteria and the criterion utilities.

3.2 Results of the Model

The input specifications describing the model can be processed to produce a matrix showing the expected utility at each node of the decision tree.

For example, the overall result of the decision tree model would be displayed in a utility matrix representing node 1 in Figure 3-1. A sample utility matrix for node 1 in the tree is shown in Figure 3-3 on the next page. The matrix shows the utility of each subordinate node (RAID, WARN, etc.) for each criterion (DOMESTIC AFFAIRS, FOREIGN AFFAIRS, etc.), and their weighted sum (TOTAL). Note that a rational decision maker should choose the course of action RAID since it leads to the maximum expected utility (63) based on the decision maker's expression of preference and belief.

Intermediate utility matrices can be obtained for any node in the decision tree model. The intermediate results are displayed in a matrix of the type shown in Figure 3-3.

1 RAMBO CRISIS

CRITERIA:	DOM-A	FOR-A	NAT-S	
CRIT. WEIGHTS:	30	20	50	TOTAL
1) RAID	42	55	78	63
2) WAR	48	59	43	48
3) WAIT	58	72	35	50
4) AGENT	61	60	41	51

Figure 3-3
OVERALL RESULT

3.3 Computation of Results

The results are computed from right to left in the tree, beginning with the decision outcomes and ending with the primary decision node. The process is known as rolling back the tree and proceeds as follows.

3.3.1 Total utilities - The total utility associated with any node is the weighted combination of the associated utility for each criterion. For each node, the total utility, U, is obtained by weighting and adding the component utilities contributed by the q criteria in accordance with the following formula:

$$U = \sum_{i=1}^{q} w_i u_i$$

where w_i is the weight of criterion i and u is the utility with respect to that criterion.

3.3.2 Probability nodes - The expected utility, $\bar{U}$, associated with a probability node (designated by the letter

W) having N possible outcomes is obtained by the following formula:

$$\bar{U} = \sum_{j=1}^{N} p_j U_j$$

where p_j is the probability of the j^{th} outcome and U_j is its associated utility. Note that since the computation proceeds from right to left on the decision tree, the utilities of the branches will have been previously computed.

3.3.3 Decision nodes - The utility associated with a decision node (designated by the letter D) having several alternative decisions is always identical to that of the alternative having the highest overall utility. The reason is that a rational decision maker should not choose an alternative having a lower expected utility. Again note that the utilities of the various decision alternatives will have been previously computed.

3.4 Probability Tags

As a convenience to the user, DECISION permits the user to tag those events that share identical outcomes having identical outcome probabilities. Once the events are tagged, the outcome probabilities need only be assigned once; all events having the same tag will be assigned the same probabilities.

A probability tag is an arbitrary letter of the alphabet. It appears as the last character in the node identification number, separated from the designator (D or W) by a comma. For example, in Figure 3-2 three different tags could be used, as follows:

```
1.1,RAID,W,A
1.2,WARN,W,A
1.3,WAIT,W,A
1.4.1.1,RAID,W,A
1.4.1.2,WARN,W,A
1.4.1.3,WAIT,W,A

1.4.2.1.1,RAID,W,B
1.4.2.1.2,WARN,W,B
1.4.2.1.3,WAIT,W,B

1.4.2.2.1,RAID,W,C
1.4.2.2.2,WARN,W,C
1.4.2.2.3,WAIT,W,C.
```

4.0 DECISION FUNCTIONS

DECISION is designed to perform the basic functions described below. A description of the detailed logical design of the DECISION function is contained in the manual, DECISION System Specification, reference 1.2.3.

DECISION consists of two subsystems: STRUCTURE and RUN. STRUCTURE is used to construct a decision tree model. RUN is used to display the results of a previously constructed decision tree model.

4.1 Functions Performed Both in STRUCTURE and RUN

4.1.1 Maintain a library of DECISION models - Store various decision tree models, filed by their associated labels.

4.1.2 Load an existing DECISION model - Display the labels of those decision tree models stored in the model library, and permit the user to retrieve any desired model. The loaded model is referred to as the current model.

4.1.3 Save the current model - Permit the user to add the current model to the model library, or to replace an existing model with the current model by designating the same model label.

4.2 Functions Performed Only in the STRUCTURE Subsystem

4.2.1 Create a new DECISION model - Permit the user to create a new decision tree model, which then becomes the current model. The user creates a model by specifying all

of the elements listed in Sections 3.1.1 through 3.1.7 and Section 3.1.10. Alternatively, the user may create separate sections, or branches of the decision tree model individually, later adding those sections to the overall model while in the process of creating it. Note that specifications for probabilities, weights, and utilities are entered using the RUN subsystem.

4.2.2 Revise the structure of an existing model - Permit the user to make changes to the logical structure of the current model. The user may:

a. add new nodes to the existing structure;

b. prune (remove entire sections from) an existing structure;

c. edit node names or delete single nodes; and

d. alter the logical relationship among the existing decision tree nodes by changing the node identification numbers.

Note that revisions to probabilities, criteria, and utilities are made using the RUN subsystem.

4.2.3 Develop the structure of a newly created or edited model - Organize the node identification numbers and labels in a structural format to allow for permanent storage of the model, and for the input of values as part of the RUN subsystem functions.

4.2.4 Print a review sheet - Print out the structure of the decision tree model thus permitting the user to review the current model to determine whether any structural

revision is required. A sample review sheet for the model displayed in Figure 3-2 is shown in Figure 4-1.

```
1 RAMBO D
1 1 RAID W
1 1 1 MISSILES W
1 1 2 NONE W
1 2 WARN W
1 2 1 MISSILES W
1 2 2 NONE W
1 3 WAIT W
1 3 1 MISSILES W
1 3 2 NONE W
1 4 AGENT W
1 4 1 NO CONT D
1 4 1 1 RAID W
1 4 1 1 1 MISSILES W
1 4 1 1 2 NONE W
1 4 1 2 WARN W
      .
      .
      .
1 4 2 2 REP NONE D
1 4 2 2 1 RAID W
1 4 2 2 1 1 MISSILES W
1 4 2 2 1 2 NONE W
1 4 2 2 2 WARN W
1 4 2 2 2 1 MISSILES W
1 4 2 2 2 2 NONE W
1 4 2 2 3 WAIT W
1 4 2 2 3 1 MISSILES W
1 4 2 2 3 2 NONE W
```

Figure 4-1
REVIEW SHEET

4.3 Functions Performed Only in RUN

4.3.1 Supply new values to the current model - Permit the user to supply an entire set of criteria, criteria weights, probabilities, and criterion utility scores to the

current decision tree model, as discussed in Sections 3.1.8 through 3.1.12.

4.3.2 Print a worksheet - Provide a printed worksheet on which the user may record an entire set of probabilities and utility scores. A sample utility worksheet is shown in Figure 4-2. Note that only the decision outcome nodes are assigned utilities. A sample probability worksheet is shown in Figure 4-3.

4.3.3 Display the results of the current model - Permit the user to examine the structure and content of the current model by displaying the utility associated with each node, as discussed in Section 3.2.

4.3.4 Edit the values assigned to the current model - Permit the user to make changes to the current model. The user may revise:

a. criteria names;

b. criteria importance weights;

c. criterion utility values;

d. probabilities; and

e. probability tags.

	DOM-A	FOR-A	NAT-S
1 RAMBO D			
1 1 RAID W			
1 1 1 MISSILES W	———	———	———
1 1 2 NONE W	———	———	———
1 2 WARN W			
1 2 1 MISSILES W	———	———	———
1 2 2 NONE W	———	———	———
1 3 WAIT W			
1 3 1 MISSILES W	———	———	———
1 3 2 NONE W	———	———	———
1 4 AGENT W			
1 4 1 NO CONT D			
1 4 1 1 RAID W			
1 4 1 1 1 MISSILES W	———	———	———
1 4 1 1 2 NONE W	———	———	———
1 4 1 2 WARN W			
.			
.			
.			
1 4 2 2 REP NONE D			
1 4 2 2 1 RAID W			
1 4 2 2 1 1 MISSILES W	———	———	———
1 4 2 2 1 2 NONE W	———	———	———
1 4 2 2 2 WARN W			
1 4 2 2 2 1 MISSILES W	———	———	———
1 4 2 2 2 2 NONE W	———	———	———
1 4 2 2 3 WAIT W			
1 4 2 2 3 1 MISSILES W	———	———	———
1 4 2 2 3 2 NONE W	———	———	———

Figure 4-2

UTILITY WORK SHEET

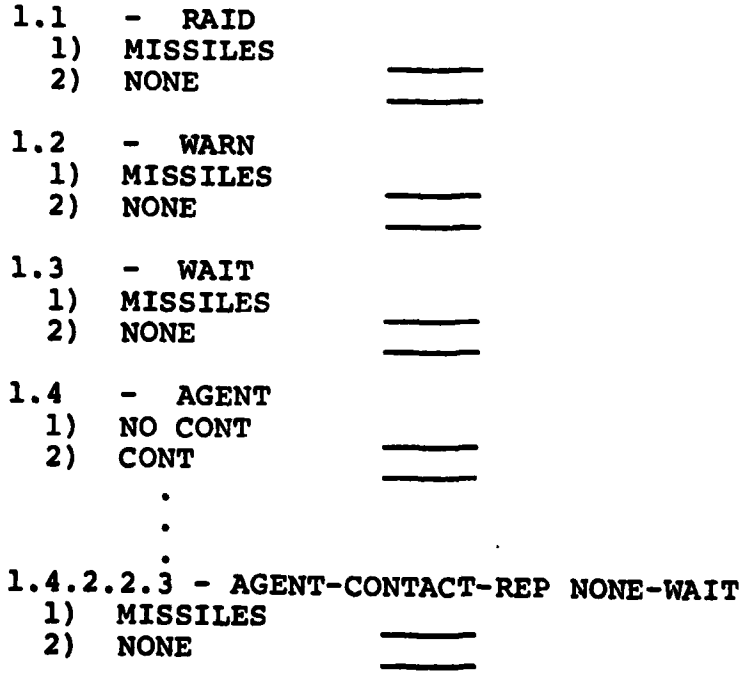

Figure 4-3

PROBABILITY WORK SHEET